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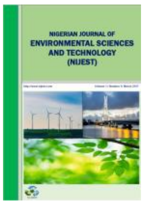

Soil Nutrient Dynamics and Potentially Toxic Elements of Sand Mining Impacted Agrarian Land in Obowo, Southeastern Nigeria

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ABSTRACT

Considering the dynamics of soil quality and pollution by potentially toxic elements (PTEs) in the soils due to sand mining in Nigeria, the study focused on the effect of upland sand mining on the agricultural land in Obowo, Southeastern Nigeria. Soil samples collected from soil depths (0-15, 15-30 cm) in eight traverse points and control, with points designated soil sampling point (SSP) ranging between SSP_1-SSP_8 and control sampling point (CSP_1). The results showed significant differences ($p<0.05$) among points. Results of the particle size distribution were in order of Sand ≥ Clay ≥ Silt, with Textural class ranging from sandy loams to loamy sandy. The mean soil pH ranged from 4.8 - 5.7 signifying moderate to strong acidity. The available P, Total N, SOC,SOM and BS ≤ control and FAO/World Reference Base. ***Effective cation exchange capacity (ECEC) (cmol/kg) (Ca^{2+}, Mg^{2+}, K^+ and Na^+), with mean Ca^{2+} 3.02, Mg^{2+}, 0.64, K^+ 0.09, Na^+ 0.10 ≤ control respectively. Exchangeable acidity recorded 1.04 ≥ control, and CEC:6.22 ≤ the control.* ***With the nutrient ratings , the soil nutrients status of the sand mined sites ranged from very low to low status for total N***(***0.02 -0.04),avail.P*** (***6.55-9.96***)***, exchangeable K, (0.07-0.14), exchangeable Ca*** (***2.25-3.55), and exchangeable Mg*** (***0.25-0.85). Except Chromium with 2.65, Copper recorded mean value of 15.21, Lead: 12.20 and Cadmium (1.80) ≥ control (zero) above the FAO/WHO permissible levels respectively. The potentially toxic heavy metals are in order of abundance in sand –mined soil: Cu ≥ Pb ≥ Cr*** **≥** ***Cd. Therefore, the area requires ecological restoration and regeneration of degraded mining site and the prohibition of indiscriminate mining activities as well as strict local control and enforcement of mining laws.***

Keywords: Mining, Heavy metal, Soil degradation, Land restoration

1.0. Introduction

In almost every mineral bearing region, soil mining and land degradation have been inseparably connected (Naveen, 2012; Naveen and Stalin, 2012). Unscientific and illegal mining has resulted to land degradation, subsidence and consequential mine fires and water table distortion resulting to topographic disorder, severe ecological imbalance and destruction to land use patterns in and around mining regions (Naveen and Stalin, 2012). Accordingly, mining industry affects the agricultural land area and induces human settlement pattern, thereby causing disruption of social relations (McKenzie, 2013). Physicochemical parameters and concentration of heavy metals- Pb^{2+}, Zn^{2+}, Ni^{2+}, Co^{2+}, As^{3+}, Cu^{2+}, Fe^{2+}, Mn^{2+} and Sn^{2+} were investigated in mined soil areas, and most parameters and metals concentration exceeded the permissible limits and concluded that ex-mining catchment has a high pollution potential due to mining activities (Ashraf *et al*., 2010).

Sand which is an aspect of soil is an economic resource in developed and developing countries of the world (Erskine and Green, 2000; Gob *et al*., 2005).This sand has been removed as an earth resource by small and large-scale mining in many parts of the country of the world for many purposes (Ezekiel, 2010; Isah, 2011).

However, if a particular area is mine for sand, agriculture in that area suffers, due to the removal of materials from the earth's surface while agriculture needs the same topsoil for cropping (Global Witness, 2010; Ubuoh *et al.*, 2013; UNEP, 2014). Nonetheless, detrimental effects of sand mining also occur outside protected areas (Kim *et al*., 2008; Ako *et al*., 2014; Padmala and Maya, 2014). In line with this, recent geographic studies of Southeast Asia's Mekong River and its delta provide evidence of geomorphic changes such as riverbed incision, subsidence and coastal erosion (Bravard *et al*, 2013; Brunier*et al*., 2014; Anthony *et al*., 2015). Furthermore, geographic studies identified sand mining as a major contributor to the geomorphic changes (Nguyen *et al*., 2015; Darby *et al*., 2016).

Mining being a potential environmental hazard has also results to clearing of vegetation, reduces essential nutrients and organic matter of the soil, reduces biological activity and decreases productivity of the soil (Akabzaa, 2000; Akabzaa and Darimani, 2001; UNEP , 2014; UN Comtrade, 2016). The previous studies have reported that soil as a reservoir of nutrients have been adversely affected anthropogenic factors (Masto *et al.*, 2015; McKenzie, 2013; Paramasivama and Siddan - Anbazhaga, 2020; Ubuoh and Ogbonna, 2018).

In Nigeria, impacts of sand mining on agriculture lands have been observed by many authors like Aromolaran (2012); Uchendu *et al.*, 2020). Ako *et al.* (2014) explained that, mining activities might result to soil nutrients' imbalance and hence poor soil health. Naveen and Stalin (2012) observed that sand mining being the process of removal of sand and gravel is becoming an environmental issue as the demand for sand increases in industry and construction leading to the removal of topsoil meant for the growth of vegetation. Above all, researchers like Aromolaran (2012), Onweremadu *et al.* (2015) worked on physicochemical characteristicsof sand mined soils in Nigeria, but did not work on potentially toxic elements in sand mined soil, and no researcher has worked on such in Obowo sand mined agricultural land.

In Obowo, agricultural activities and sand mining are vital sources of livelihood to many people living in Umuna village and its environ, with unplanned mining leading to soil erosion almost across the major road and competition with agricultural land that suffers from soil degradation . Large large-scale mining activities generally continue to reduce the vegetation of most of the mining communities to levels that are destructive to biological diversity (Akabzaa, 2000; Akabzaa and Darimani, 2001). Davis and Tilton (2005) also suggest that local communities tend to bear the negative impacts of mining – be they social, economic or environmental. It is therefore important to make effort to stem these problems through informed decision-making to address activities of sand mining and their impacts on the environment, especially agricultural land (Burrough and McDonnell, 2002; Hubler and Pothen, 2021).

According to FAO(1984), TerrAfrica (2006), about 20% of the world' s agricultural lands have been irreversibly destroyed due to accelerated land degradation and intensive land use, resulting to a reduction of about 15-30% of their productivity. This has a serious implication on food insecurity, health and safety hazards and depressed viability of the earth for food production (Helen, 2000).

This work therefore aims at studying the effects of sand mining on soil quality dynamics and the way forward in sustainable inland sand mining in Obowo specifically and Nigeria.

2.0. Methodology

2.1. Study area

Obowo Local Government Area of Imo State of Nigeria falls under Okigwe agricultural zone (Ukpongson *et al.*, 2014). The area lies between latitude 5^o 35' 0''N and 5^o 22' 30''N and longitude 7^o 22' 30''E and 7^o 25' 0''E of the State, with the total population of 64,000 people and occupies a total land area of 46,053km^2, occupy the major road linking Imo, Abia and Akwa Ibom States (Figure 1). The rainy season falls between April and October with annual rainfall varying from 1500-2200mm (60-80inches) in the area. It has mean temperature of above 20^{o}C (68^o F) and relative humidity of

75%-90% at peak rainfall (Edwin-Wosu *et al.*, 2013). The soil of the area is degraded by the activities of upland sand mining (Figure 2).

Figure 1: Map of Obowo Local Government Area of Imo State. Source Google Earth (2022).

Figure 2: Upland sand mining in the study area

2.2. Soil sampling procedure

Soil samples collected from degraded sand mining site and control from cultivated and abandoned farmland. Soil samples were taken at two depth 0-15cm and 15-30cm at established reference point (Figure 3), positioned along North-South and East-West transects at different topographical locations of landscape using the soil auger at intervals of 100m and samples were put in labelled polyethylene bags and transported to the laboratory . Soil sample was air-dried and sieved with a 2mm mesh (Allen *et al.,* 1974), prior to laboratory analysis.

2.3. Laboratory analyses

2.3.1. Soil physical characteristics

The soil particle size distributions were determined using the standard hydrometer and pipette technique (Kettler *et al*., 2001; Gee and Or, 2002). The soil texture was determined using the soil textural triangle based on the percentages of the different soil particle size (Sutherland, 1990).

2.3.2. Soil chemical characteristics

Soil pH: Soil pH was determined electrometrically using pH meter and this was done in distilled water and 0.1N KCl solution using a sol liquid ratio of 1:3.5 in a glass electrode (Thomas, 1982).

Organic Matter Content: The organic matter content of the soil samples was determined at each location and at different depths using the Wackley – Blank method (Walkley and Blacks, 1965). This method is by titrating a known volume of dichromate solution against a solution of known weight of soil. The formula given by Wackley- Blank was used in computing the percentage organic carbon as shown below:

$$\text{Percentage organic matter (\%OC)} = V_1 - V_2 \times \frac{0.003 \times 100 \times f}{W} \quad (1)$$

Where, V_1 = Volume of dichromate, V_2 = volume of titrant (Ferrous ammonium sulphate), W = weight of air-dried soil, f= correction factor (usually 1.33), and Percentage organic matter (% OM) = %OC × 1.724.

The percentage of soil organic carbon: The percentage of soil organic carbon measured using method by Walkley and Blacks (1965). Percentage soil organic matter considered the total carbon multiplied by a conversion factor of 1.72 (Chikwendu *et al*., 2019).

Total Nitrogen: Total nitrogen was determined by macro kjeldahl method as described by Bremner (2006) using $CuS0_4/Na_2S0_4$ catalyst mixture.

Available phosphorus: Available phosphorus was determined using the Bray No. 1 extraction method (Bray and Kurtz, 1945).

Potassium and Sodium determined by the flame emission photometer.

Exchangeable Bases : The exchangeable bases (Ca^{2+}, $Mg^{2+,}$ K^+) were extracted with neutral normal ammonium acetate (NH_4OAC) buffered at pH 7.0 (Thomas, 1982). Exchangeable Calcium and Magnesium was determined in the extract by ETDA titration, while Potassium and Sodium was determined by the use of Flame Photometer (Udo *et al.*, 2009). Calcium was determined using the ethylene-diamine–tetracettic-acid (EDTA) method (Allison, 1973).

Exchangeable acidity: Exchangeable acidity ($Al^{3+,}$ H^+) was determined by the titrimetric method of Mclean (1965), Juo (1975).

Effective Cation Exchange Capacity .Effective Cation Exchange Capacity (ECEC) was obtained as the summation of exchangeable cations and exchangeable acidity.

Percentage Base Saturation (PBS): Percentage Base Saturation (PBS) was obtained by dividing sum of exchangeable bases by cation exchange capacity and multiplying by 100, and expressed as:

$$Percentage\ Base\ Saturation\ (\%) = \frac{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+} + \mathrm{K}^{++} + \mathrm{Na}^{+} \times 100}{\mathrm{CEC}} \quad (2)$$

Thereafter, the result was compared with the acceptable nutrient standards for soil quality for agriculture by FAO/WHO, and other important environmental standards respectively.

2.3.3. Soil heavy metals digestion

Before digestion to analyse heavy metals, each soil sample was dried at 65 °C for 48 h (Zeng-Yei, 2004). Aqua-regia wet digestion was used for the estimation of the selected heavy metals (Enyoh *et al.*, 2017), by using ICP-MS/OES best method to digest the soil completely with tri-acid ($HNO_3/HClO_4/H_2S\ O_4$ /HF/HCl/HNO_3) under fume hood with a temperature of 160 degree for 6 hrs for two days till the soil solution was completely digested (Zeng-Yei, 2004). The extractants were

prepared using mixed concentrated HCl with concentrated HNO_3 in 3:1 and mixture allowed to mix properly for 5 hours; 10 g of soil samples were taken in acid-washed beakers and 30 ml of aqua-regia was introduced. The mixture was reduced to 10–20 mL by heating at 9^0C on a hot plate (Enyoh and Beniah, 2020). Accordingly, the mixture reduced was allowed to cool and made to a final volume of 50 mL by addition of de-ionized water, followed by filtration resulting to filtrate.

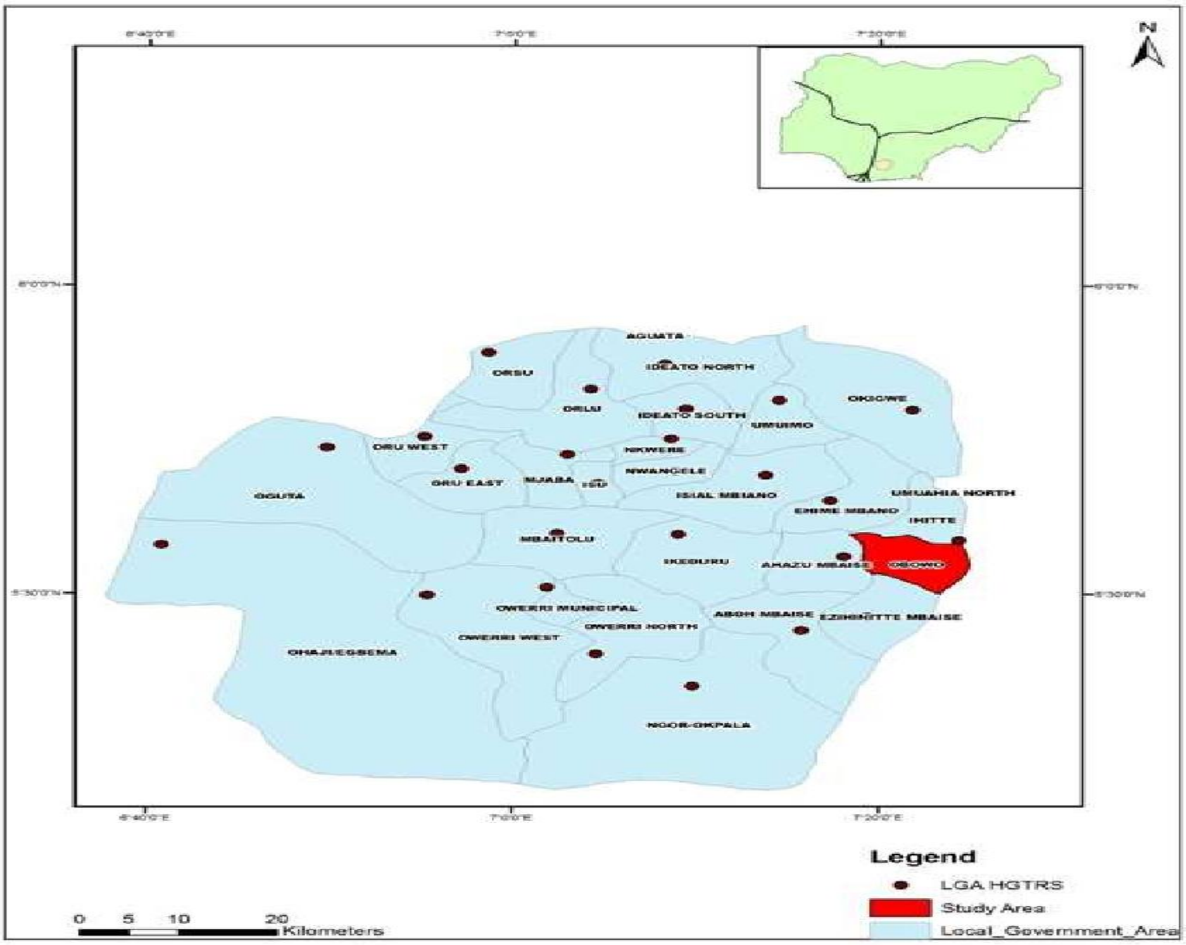

Figure 3: Imo State showing study area (Obowo LGA.)
Adapted: Edwin-Wosu *et al*. (2013).

2.3.4. Soil heavy metal determination
The concentrations of Iron (Fe), Zinc (Zn), Lead (Pb), Cadmium (Cd), and Copper (Cu in the final solutions were determined by an atomic absorption spectrometer (AAS) (Hitachi Z-8100, Japan). .

2.3.5. Experimental design and statistical analysis
A simple factorial experiment was conducted in a randomized complete block design with three replications in dust particles. Data generated from the experiment were subjected to one way analysis of variance (ANOVA) using statistical package for the social sciences (SPSS) v. 20 and means were separated (Steel and Torrie, 1980) at $P < 0.05$ using Duncan's Multiple Range Test (DMRT) while Correlation analysis was used to measure the relationship existing the means of the parameters analyzed in sand mined soil at different sampling points.

3.0. Results and Discussion

The results of the physical and chemical properties of the soils from different sampling locations at different depths: 0-15cm and 15-30cm are presented in Tables 1-6.

Table 1: Mean ±SD of Soil Fractions and texture of Soil impacted by upland sand mining in the study area

Soil Sampling Point	Depth(cm)	Soil fractions			Soil Texture
		Sand %	Silt %	Clay %	
1. Soil sampling point (SSP) - A_1	0-15	83.61±0.69^e	4.35±0.07^a	11.75±0.35a	LS
	15-30	72.35±0.07^c	9.35±0.07^c	13.57±1.06b^c	SL
2. Soil sampling point (SSP) --B_1	0-15	75.35±0.07^{ab}	4.35±0.07^a	12.75±0.35a^c	LS
	15-30	74.35±0.07^a	4.35±0.07^a	17.75±0.35^d	SL
3. Soil sampling point (SSP) - C_1	0-15	86.45±0.07^b	7.35±0.07^b	13.75±0.35^{bc}	LS
	15-30	76.45±0.07^b	7.55±0.77^d	17.75±0.35^d	SL
4. Soil sampling point (SSP) - D_1	0-15	70.55±0.77^d	7.85.±0.77^{fg}	11.75±1.06^{bc}	LS
	15-30	82.55± 0.77^f	7.76±0.77^f	14.75±1.06^c	SL
Overall Mean	-	77.71± 0.32	6.62± 0.33	21.35±0.53	-
Soil sampling point (CSP) -Control	0-15	81.55±0.77^f	75.55±0.77^e	14.75±1.06^c	SL
	15-30	79.55±0.77$_e$	79.55±0.63^g	18.75±1.06^d	SL
Overall Mean	-	80.55±0.77	77.55±0.2	16.75±0.06	-

Different letters on the same column means there is a significant increase at P≤0.05, while same letters on the same column means no significant increase at P≤0.05

3.1. Particle size distribution in upland sand mining sites

The sand fraction in inland mining site ranged from 70.55±0.77-86.45±0.07% that fluctuates in depths, having mean value of 77.71± 0.32%, less than control with sand fraction of 80.55±0.77% ≥ the World Reference Base 63% sand (FAO, 2006; 2014). The mean result of sand from inland sand mining of the study within 77.80% of sand in Itagunmodi, 73.80% in Awo, 67.90 in Ijero-Ekiti in soils of South -western Nigeria (Oluwatosin *et al.*,2014). Sandy soils of the area could be linked to the effects of parent materials (Coastal Plain Sands), land use types and climate (Uzoho and Oti 2005; Onweremadu, 2007). As regards sand, there exist significance differences among soil depths, while some did not have respectively at P<0.05. Silt content arranged from4.35±0.07-9.35±0.07%, with the mean value of 6.62± 0.33% less than 77.55±0.2% as control and below the 30% silt stipulated by World Reference Base FAO (2014). The mean result of silt in inland sand mining under studied is less 13.40 % in Awo, 11.40 in Itagunmodi, 15.4% in Ijero-Ekiti, in soils of south western Nigeria (Oluwatosin *et al.*, 2014). Clay content in mining soil samples ranged between 14.75±1.06 % with the mean value of 21.35±0.53%, greater than control with 16.75±0.06%, and above the 7% clay World Reference Base (FAO, 2014). The higher clay fraction in subsurface layer than in the top surface soil may indicate possible clay translocation from the top layer to the layer (McKenzie, 2013; Masto *et al.*, 2015). The mean value of clay of this study is greater than sand mining sites in Awo (13.40%), Itagunmodi (11.40%), and Ijero-Ekiti (15.4%) respectively (Oluwatosin *et al.*, 2014). Particle size distribution in this study showed was order of: Sand ≥ Clay ≥ Silt, with sand dominating (Table 2). The dominance of sand particle size over clay implies that sand originate from parent materials and rock fragments genetically and sequentially produced sand, then silt, and these sizes are transformed into clay with intense weathering and pedogenesis (Onwerremadu *et al.,* 2015). The clay contents obtained were in accordance with the report of Dauda and Odoh, (2012). Egharevba and Odjada (2002) reported similar observation of low % of clay in some soil samples. The high mean clay-silt ratios ranging from 7.0- 21.34 in the study is greater than 8 – 10 silt-clay ratios obtained in soils closest to the mine site (Onwerremadu *et al.*, 2015), signifying that mine soils show either some development (Inceptisols) or exhibits little or no development (Entisols) (Thomas *et al*.,2000).

Textural class of the soils varied between sandy loams to loamy sandy soil. Similar textural classes of loamy sand and sandy loam were obtained in coastal plain soils in Owerri, Southern Nigeria (Oguike and Mbagwu, 2009). The increased clay fraction with increasing soil depth and the lowest overall mean proportion of clay fraction compared to the sand and silt fractions are consistent with the findings of Yimer *et al*. (2006), Sintayehu (2006), Awdenegest *et al*. (2013). Moreover, the textural class across the inland sand mining sites recorded sandy loam, indicating the homogeneity of soil forming processes and similarity of parent materials (Foth, 1990).This means that the soils within the study sites have similar appearance throughout the surface area.

Table 2: Mean ±SD of the chemical characteristics of sand mining degraded agricultural soil in the study area

Soil Sampling Point	Soil depth-	pH (H_2O)	Av.P mg/kg	N %	OC %	OM %	BS %
SSP- A_1	0-15 cm	$4.50±0.70^{a}$	$8.92±1.30^{bc}$	$0.03±0.00^{abc}$	0.00±0.44a	$0.54±0.00^{e}$	$72.15±0.00^{c}$
SSP- A_2	15-30 cm	$4.75±0.35^{ab}$	$6.55±0.78^{a}$	$0.02±0.01^{a}$	$0.13±0.00^{ab}$	$0.23±0.00^{a}$	$64.60±0.00^{b}$
SSP-B_1	0-15 cm	$5.55±0.63^{b}$	$9.72±1.02^{c}$	$0.04±0.00_{c}$	$0.42±0.00b^{c}$	$0.72±0.00^{f}$	$71.46±0.00^{c}$
SSP-B_2	15-30 cm	$4.70±0.42^{ab}$	$7.56±0.79^{bc}$	0.02±0.00a	$0.16±0.00^{abc}$	$0.28±0.00^{b}$	$63.85±0.07^{b}$
SSP- C_1	0-15 cm	$4.50±0.70^{ab}$	$9.65±0.91^{c}$	$0.03±0.00^{abc}$	$0.23±0.00^{abc}$	$0.40±0.00^{d}$	$73.97±0.00^{d}$
SSP- C_2	15-30 cm	$4.80±0.28^{ab}$	$7.91±0.12^{ab}$	$0.02±0.00^{ab}$	$0.20±0.00^{abc}$	$0.36±0.00^{c}$	$65.24±0.34^{b}$
SSP- D_1	0-15 cm	$5.60±0.56^{b}$	$9.96±0.04^{c}$	$0.04±0.00_{bc}$	$0.50±0.00^{c}$	$0.86±0.00^{a}$	$72.24±0.33^{c}$
SSP- D_2	15-30 cm	$3.80±1.13^{a}$	$7.60±0.55^{ab}$	$0.02±0.00^{ab}$	$0.20±0.00^{abc}$	$0.36±0.00^{c}$	$59.66±0.94^{a}$
Mean	-	4.8±0.47	8.11±0.69	0.03±0.01	0.23±0.44	0.44±.00	67.90±0.19
CSP-Control $_1$	0-15	$5.70±0.98^{b}$	$18.90±0.14^{e}$	$0.27±0.00^{e}$	$1.77±0.00^{e}$	$3.07±0.00^{i}$	$92.96±1.36^{f}$
CSP- Control $_2$	15-30	$5.75±0.35^{b}$	$12.80±0.28^{d}$	$0.10±0.00^{d}$	$1.02±0.00^{d}$	$1.76±0.00^{h}$	$83.93±1.31^{e}$
Mean		5.73±0.67	13.51±0.21	0.19±0.00	1.40±0.00	2.42±0.00	88.45±1.34

Different letters on the same column means there is a significant increase at P≤0.05, while same letters on the same column means no significant increase at P≤0.05

3.2. Chemical characteristics in inland sand mining sites

The pH in water of the soils in mining site ranged from 3.80-5.60, with the mean value of 4.8 ≤ the control with pH 5.7. The mean value of pH in the sand mined soil signifies strong acidity as < pH5.5 is strongly acidic (Ubuoh and Ogbonna, 2018; Yebpella *et al.*, 2020), probably due to the overburden parent materials, that are acid producing (Onweremadu *et al.*, 2015; Uchendu *et al.*, 2020), and moderately acidic (pH 5.2 – 6.2) (Singer and Munns, 1999). This agreed with the finding of Kayode *et al*, (2019) who reported the slightly acidic soils in Ebonyi State and the strongly acidic soils found in Imo and Abia States respectively. The result of this study is consistent with the finding of Ghose, (2005) who reported pH varying from 4.9 to 5.3 in a mining dumpsite situated in Central Coalfield Limited's (CCL). Available Phosphorus (Av. P, $mgKg^{-1}$) in the mined soil ranged from 6.55-9.96 mg kg^{-1}, with the mean value 8.11±0.69 mg /kg^{-1}less than the control with the mean value of 13.51±0.21 mg/ kg^{-1}, all less than Maximum Tolerable limits of 20mgkg-1 (Holland *et al*., 1989).The mean value of the avail. P. of the study is less than sand mining soil that recorded 13.94 in Awo, ≥8.56 in Itagunmodi and ≤55.90 in Ijero-Ekiti (Oluwatosin *et al*., 2014). The decreased phosphorus in mining site was reported by Adewole and Adesina (2011), Ghosh (2002), Naveen and Stalin (2013), Oluwatosin *et al*. (2014) against increased in agricultural land as control.

Total Nitrogen (TN, %) ranged from 0.02±0.00 -0.04±0.00 %, with the mean value of 0.03±0.01% less than 0.19±0.00% as control. The lower contents of total nitrogen comes from biomass removal during sand mining, since most soil nitrogen is bound in organic carbon which is in tandem with the findings of Naveen and Stalin (2012), Awdenegest *et al.* (2013). The result of the study site is ≤ Maximum Tolerable limits of 0.20% for TN (Miller and Donahue, 1995). Soil Organic Carbon Content (SOC%) ranged from0.00±0.44-0.50±0.00 %, with the mean of 0.23±0.44% ≤ control with the mean value of 1.40±0.00% .The low OC suggests the reduced organic materials as a result of continuous sand mining for long period of time without remediation (Girmay *et al.*, 2008; Larney and Angers, 2012). The result of the study site is ≤Maximum Tolerable limits of 2.0% (Miller and Donahue, 1995). The removal of vegetation and top soil (Salami *et al*., 2002), had been found to have adverse effect on humid tropics' soil organic matter. Reduction in soil organic carbon due to conversion of forests into more intensive land uses have been reported (Onweremadu *et al*., 2008).

Soil Organic matter (SOM, %) has an association with degradation of soil and environmental conditions in tropical and subtropical regions (Azlan *et al.*, 2012), whose status depends on biomass input and management, mineralization, leaching an erosion (Roose and Barthes, 2001; Ubuoh *et al*., 2013). The OM ranged from 0.23±0.00 -0.86±0.00%, with the mean value of 0.44±.00% ≤ 2.42±0.00% of OM as control, suggests being due to sand mining. Aggregate structure breaks down as successive layers of soil are removed and stockpiled elsewhere on the site when mining begins, leading to low degree of nutrient availability in the soil (Heras, 2009), and may increase erosion potential that discourages long term soil carbon sequestration (Ubuoh *et al.*, 2016).

Percent base saturation (PBS) ranged from59.66±0.94-72.15±0.00%, with the mean value of 67.90±0.19 less then control with 88.45±1.34%, greater than31.94-47.56% (Nnabuihe, 2014), less than 60.6% (Anyanwu *et al.*, 2019) who reported low percentage base saturation in sand mining sites in Nigeria. Poor base saturation may have been influenced by increase in soil acidity in mining site (Ubuoh*et al*., 2013).

Table 3: Mean ±SD values for soil cation exchange parameters in upland sand mining sites

Stations	Soil depth	Ca	Mg	K	Na	EA	CEC
SSP- A_1	0-15	3.40 ± 0.00^{e}	0.85 ± 0.07^{c}	0.14 ± 0.00^{d}	0.11 ± 0.00^{ab}	1.72 ± 0.00^{c}	$6.17\pm 0.00b^{c}$
SSP- A_2	15-30	2.80 ± 0.00^{c}	0.45 ± 0.07^{b}	0.08 ± 0.00^{ab}	0.08 ± 0.00^{a}	1.84 ± 0.00^{c}	5.70 ± 0.71^{b}
SSP-B_1	0-15	3.20 ± 0.00^{d}	0.85 ± 0.07^{c}	0.12 ± 0.00^{c}	0.15 ± 0.06^{ab}	1.68 ± 0.00^{cd}	5.87 ± 0.02^{bc}
SSP-B_2	15-30	2.60 ± 0.00^{b}	0.25 ± 0.07^{a}	0.10 ± 0.01^{b}	0.08 ± 0.00^{a}	1.74 ± 0.00^{c}	4.83 ± 0.01^{a}
SSP- C_1	0-15	3.60 ± 0.00^{f}	0.85 ± 0.07^{c}	0.12 ± 0.00^{c}	$0.15\pm 0.06a^{bc}$	1.65 ± 0.00^{cd}	6.38 ± 0.00^{cd}
SSP- C_2	15-30	2.82 ± 0.02^{c}	0.45 ± 0.07^{b}	0.07 ± 0.00^{a}	0.07 ± 0.00^{a}	1.76 ± 0.00^{c}	5.15 ± 0.07^{a}
SSP- D_1	0-15	3.55 ± 0.07^{f}	0.85 ± 0.07^{c}	0.12 ± 0.00^{c}	0.11 ± 0.00^{ab}	1.72 ± 0.00^{c}	6.22 ± 0.03^{bc}
SSP- D_2	15-30	2.25 ± 0.07^{a}	0.55 ± 0.07^{b}	0.08 ± 0.00^{ab}	0.07 ± 0.00^{a}	1.88 ± 0.00^{c}	4.72 ± 0.02^{a}
Mean		3.02±0.05	0.64±07	0.09± 0.00	0.10± 0.00	1.75± 0.00	6.22±0.03
CSP-Control 1	0-15	6.25 ± 0.07^{h}	2.85 ± 0.07^{c}	0.38 ± 0.00^{f}	0.22 ± 0.00^{c}	-0.00 ± 0.88^{a}	10.21 ± 0.01^{e}
CSP- Control 2	15-30	4.25 ± 0.07^{g}	1.25 ± 0.07^{e}	0.25 ± 0.00^{e}	0.18 ± 0.00^{bc}	1.04 ± 0.00^{b}	6.85 ± 0.02^{d}
Mean		5.25±0.07	2.05±0.07	0.32± 0.00	0.2± 0.00	1.04± 0.88	8.53±0.02

Different letters on the same column means there is a significant increase at P≤0.05, while same letters on the same column means no significant increase at P≤0.05

3.3. Effective cation exchange capacity (ECEC in inland sand mining sites.

Exchangeable basic cations (Ca, Mg, K and Na) of the soil differed significantly (P<0.05) among the soils. Effective cation exchange capacity (ECEC) signifies the summation of all exchangeable bases (Ca^{2+}, $Mg^{2+,}$ K^{+} and Na^{+}). Therefore, Calcium ranged from 2.25± 0.07-2.25± 0.07 cmol/kg, with the mean value of 3.02±0.05 cmol/kg ≤ control with 5.25±0.07 cmol/kg. The result is less than Ca^{2+}: 14.96 - 30.13 cmol/kg of (Awo, Itagunmodi and Ijero-Ekiti) (Oluwatosin *et al*., 2014). Magnesium ranged from 0.25±0.07-0.85±0.07 cmol/kg, with the mean of 0.64±07 cmol/kg ≤ control with the mean of 2.05±0.07 cmol/kg. Potassium ranged 0.07±0.00-0.14±0.00 cmol/kg with the mean of 0.09± 0.00 cmol/kg ≤ control with the mean value of 0.32± 0.00 cmol/kg and Sodium (Na^{+}) ranged from 0.07± 0.00-0.15± 0.06 cmol/kg with the mean of 0.10± 0.00 cmol/kg ≤ controls with the mean of 0.2± 0.00 cmol/kg. Basuk *et al*. (2018), reported that, Organic levels of Ca, Mg, C and soil N recorded lower values on soil with a sandy soil than on agricultural land due to loss of vegetation cover and soil solum by anthropogenic activities (Ubuoh and Ogbonna, 2018).

Exchangeable acidity (EA) ranges from 1.65± 0.00-1.88± 0.00 cmol/kg with the mean of 1.75± 0.00 cmol/kg ≥ control having the mean value of 1.04± 0.88 cmol/kg. The result is consonant with the finding of Aromolaran (2012) who reported 1.6 cmol/kg of EA due to sand mining activities on land in agrarian communities in Ogun State. The result of EA of this study is low when compared with a medium range of 2.1-4 $cmolkg^{-1}$ (Holland *et al*., 1999).

The cation exchange capacity (CEC) of the study ranged from 4.72± 0.02- 6.38± 0.00 cmol/kg with the mean value of 6.22±0.03 cmol/kg ≤ the CEC value 8.53±0.02 cmol/kg as control. The result is in consonant with the finding of Wasis *et al*. (2018) WHO reported low CEC on ex-mining land that triggered by the loss of clay fraction due to washing of clay material and soil erosion in West Java Province, Indonesia.

3.4. Effects of upland sand mining on soil nutrients

From Table 4, the rating of nutrients indicated that total nitrogen in the sand mined soil was very low ranging from 0.02 -0.04% ≤ T. Nitrogen(0.08%) in sand mining site leading sand to land degradation in agrarian community (Aromolaran,2012). Available P was low ranging between 6.55-9.96%, exchangeable K+ recorded very low ranging from 0.07-0.14meg/100g), exchangeable Ca^{2+} was low ranging from 2.25-3.55 meg/100g, within the range of 3.6$cmolkg^{-1}$ in sand mining site (Aromolaran,2012), and exchangeable Mg^{2+}meg/100g was between very low–low (0.25-0.85) according to the ratings of soil nutrients by Loganathan (1987). The low mean values of ECEC in the sand mining study site is an indicative of the low capacity of the soils to retain nutrient elements

due to the insufficient amount of organic matter and soil pH chemistry originating from anthropogenic activities destroying agricultural soil (Smith *et al.,* 1994; Ubuoh *et al.*,2013; Ubuoh *et al*.,2020). The low exchangeable variables from the upland sand mining soil is probably due to the removal of vegetation cover as a result of mining operations.

Table 4: Comparison of soil nutrients with inland sand mining degraded agricultural soil in the study locations and ratings of soil nutrients

Soil nutrients	Ratings of soil nutrients					The study: Inland sand	Remark
	Very low			High	Very high		
(total N,%)	<0.05	0.05–0.15	0.15–0.20	0.20–0.30	>0.30	0.02 -0.04	Very low
(available P, Bray and Kurtz No.1, ppm)	<3	3 – 10	10 – 20	20 – 30	> 30	6.55-9.96	Low
(exchangeable K, meg/100g)	<0.2	0.2–0.3	0.3–0.6	0.6–1.0	> 1.0	0.07-0.14	Very low
(exchangeable Ca meg/100g)	<2	2 – 5	5 – 10	10 – 20	> 20	2.25-3.55	Low
(exchangeable Mg, meg/100g)	<0.3	0.3–1	1 – 3	3 – 8	> 8	0.25-0.85	Very low-low

Source:Loganathan (1987)

Table 5: Mean ±SD of heavy metal concentrations in sand mining degraded agricultural soil in the study area

Sample	Soil depth(cm)	Cu (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
SSP - A_1	0-15	$18.30{\pm}0.42^c$	$12.30{\pm}0.42^f$	$4.10{\pm}0.14^c$	$2.30{\pm}0.42^{cd}$
SSP - A_2	15-30	$11.10{\pm}0.14^b$	$15.05{\pm}0.07^b$	$1.44{\pm}0.62^b$	$0.74{\pm}0.06^b$
SSP - B_1	0-15	$20.15{\pm}0.21^c$	$13.10{\pm}0.14^g$	$3.45{\pm}0.64^c$	$2.10{\pm}0.14^c$
SSP - B_2	15-30	$10.30{\pm}0.42^b$	$6.20{\pm}0.28^c$	$1.36{\pm}0.51^b$	$0.80{\pm}0.00^c$
SSP - C_1	0-15	$19.20{\pm}0.28^c$	$12.45{\pm}0.63^f$	$4.07{\pm}0.09^c$	$2.40{\pm}0.56^{cd}$
SSP - C_2	15-30	$12.30{\pm}0.42^b$	$7.05{\pm}0.07^d$	$2.05{\pm}0.07^b$	$0.62{\pm}0.03^b$
SSP - D_1	0-15	$19.30{\pm}0.42^c$	$11.40{\pm}0.56^e$	$3.40{\pm}0.56^c$	$2.70{\pm}0.00^d$
SSP - D_2	15-30	$11.05{\pm}0.07^c$	$6.10{\pm}0.14^c$	$1.38{\pm}0.54^b$	$0.80{\pm}0.00^b$
Overall		15.21±0.29	12.20±2.02	2.65±6.70	1.80±0.30
FAO/WHO		2.0	10	50	1.0
CSP - C_1	0-15	$6.05{\pm}8.40^b$	$0.07{\pm}0.00^a$	ND	ND
CSP - C_2	15-30	$0.04{\pm}0.00^a$	$0.01{\pm}0.00^a$	ND	ND
Overall		3.05±8.40	0.04 ±0.00	-	-

SSP= Soil sample point; CSSP= Control soil sample point

3.5. Effect of inland sand mining on potentially toxic heavy metals

From the result obtained in Table 4, it was observed that the soil concentration of copper in sand mining soil ranged from11.05±0.07 - 20.15±0.21 mg/kg, with the mean value of 15.21±0.29 mg/kg > control mean value of 3.05±8.40 mg/kg, all above the permissible of 2.0mg/kg Cu for agricultural soil that is stipulated by WHO (1989). This result indicated that copper in mined- soil is in excess. Based on environmental and health (EH) impacts of copper, it is only limited numbers of plant has a chance to survive (Ako *et al.,* 2014).When soils are polluted with copper, human beings and animals are likely to suffer from liver and kidney problems when ingested or breathed in excess (Lenntech, 1999; Ako *et al*., 2014). Lead content ranged from6.10±0.14 -15.05±0.07 mg/kg, with the mean value of 12.20±2.02mg/kg > the control with 0.04 ±0.00 mg/kg. The mean value of Pb in the sand mined soil is above the 10 mg/kg of agricultural soil (WHO, 1989). Therefore, a high level of lead in the sand-mined sites can result to negative impact that affects man and environment through agricultural activities. Plants absorbing the lead through their roots and their leaves and consumed by man and animals can result to lead poisoning, hence disorders to the heart, kidneys, reproductive and nervous system (Lenntech, 1999). Chromium ranged from 1.36±0.51-4.10±0.140mg/kg, with the mean value of 2.65±6.70 mg/kg < the permissible of 50 mg/kg agricultural (WHO, 1989) and control having no concentration of Cr in soil.

Cadmium ranged from 0.74±0.06-2.70±0.00 mg/kg, with the mean value of 1.80±0.30 mg/kg, and control site recording zero Cd concentration. The mean value of Cd in the study site is exceeding the

Maximum Allowable Limits (0.1 mg kg^{-1}) set by the Codex Alimentarius (Oliva *et al.,* 2019), and they also exceed the maximum tolerable intake of Cd set by FAO and WHO (FAO, 2014). Ojiako and Aduaka (2015) and Ubuoh *et al*. (2018) have reported that cadmium is highly toxic metal, and had not been known to have any beneficial effects on plants and animals. Earthworms and other essential soil organisms are also extremely susceptible to cadmium poisoning at high concentration (Ako *et al*., 2014).The potentially toxic heavy metals are in order of abundance in sand –mined soil: Cu ≥ Pb ≥ Cr ≥ Cd, with copper dominating the soil (Figure3).

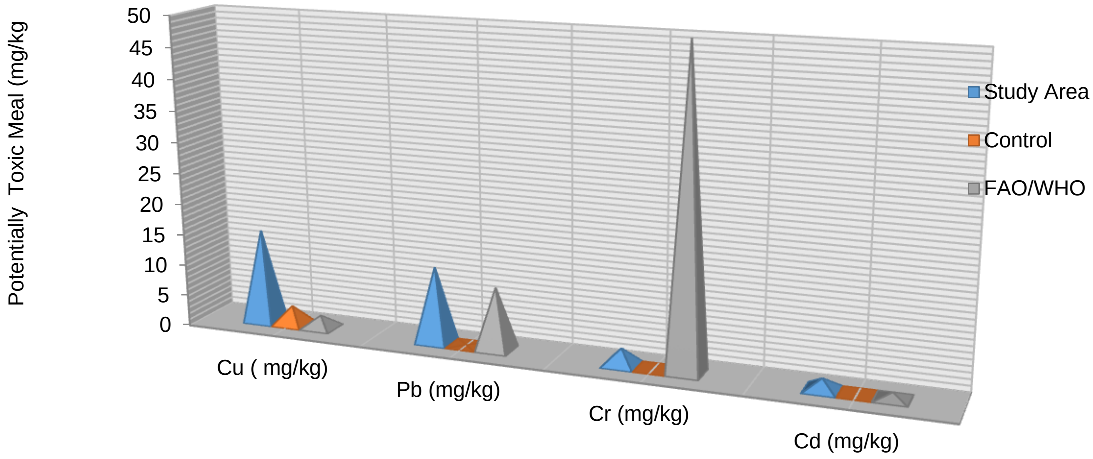

Figure 3: Comparison of potentially toxic metals with FAO/WHO STD in inland Sand mining sites

3.6. Correlation of soil parameters in upland sand mining site

The interrelationship of different parameters is useful in studying the association of soil parameters (Andrew *et al.,* 2018). The physicochemical characteristics and potentially toxic metals in mined soil in the study area displayed an inter-relationship of Pearson correlation matrix in Table 7. Silt recorded very high positive correlation between organic carbon and organic matter in mining affected soil. Bechtold and Naiman (2006) and Cabezas and Comín (2010) observed that total organic carbon (TOC) storage in the soils were strongly correlated with the concentrations of fine particles. The association of silt with organic compound suggests sand mining with no vegetation outgrowth. Wang *et al*. (2000) have also found that SOM in the topsoil has a lower concentration due to the sparse vegetation that induced severe soil erosion and degradation. Accordingly, anthropogenic activities and management also affect SOM concentration greatly (Ubuoh *et al*., 2016; Ubuoh *et al*., 2020a, 2020b). Above all, though the soil pH is not an indicator of fertility, but it shows very high correlation with the avail. P. and Ca in sand-mined soil, but it affects soil acidity and mobility of some selected heavy metals .The macronutrients like nitrogen and potassium (K) play a key role in the healthy growth of the vegetation (Paramasivama and Anbazhagan, 2020). The study locations recorded low supply of these macronutrients due to sand mining. Further, the study of soil samples infers that, the Organic carbon positively correlated with total nitrogen and potassium, and organic matter correlated with K. Positive association existed between TN and K. Avail. /k and Na; Ca/; K and Mg; Mg/K; K/Na; EA/Cu; Cu/Pb; Pb/Cr; and Cr/Cd, at $P \leq 0.05$ respectively. The positive correlation matrix of heavy metals such as Cu, Pb, Cr and Cd in the sand mining site have created an impression that these potentially toxic metals have same possible anthropogenic and natural sources like inland sand mining, rock and soil weathering (Ubuoh *et al.,* 2021). Yebpella *et al.* (2020) reported that the positive associated is an indication of the positive geochemical and probable mineralogical relationship among potentially toxic elements in soil.

Table 6: Correlation Analysis among the physicochemical properties and heavy metals of the sand mined sites

Item	Sand	Silt	Clay	pH	OC	OM	TN	AV.P	Ca	Mn	K	Na	EA	Cu	Pb	Cr	Cd
Sand	1																
Silt	-0.76**	1															
Clay	-0.88**	0.36	1														
pH	-0.17	0.56*	-0.18	1													
Oc	-0.51*	0.74**	0.18	0.88**	1												
OM	-0.51*	0.74**	0.18	0.88**	1.00**	1											
TN	-0.44	0.71**	0.10	0.87**	0.98**	1.00**	1										
Av.P	-0.41	0.70**	0.07	0.93**	0.97**	0.97**	1.00**	1									
Ca	-0.30	0.64**	-0.05	0.93**	0.93**	0.93**	0.95**	0.97**	1								
Mn	-0.39	0.67**	0.06	0.87**	0.96**	0.96**	0.94**	0.96**	0.94**	1							
K	-0.50*	0.74**	0.17	0.87**	0.98**	0.98**	0.98**	0.98**	0.94**	0.96**	1						
Na	-0.50*	0.73**	0.18	0.90**	0.97**	0.97**	0.94**	0.98**	0.93**	0.93**	0.98**	1					
EA	0.61**	-0.75**	-0.31	-0.83**	-0.97**	-0.97**	-0.95**	-0.96**	-0.91**	-0.93**	-0.92**	-0.98**	1				
Cu	0.91**	-0.74**	-0.77**	-0.34	-0.69**	-0.69**	-0.64**	-0.57**	-0.48	-0.60**	-0.69**	-0.67**	0.76**	1			
Pb	0.91**	-0.70**	-0.80**	-0.24	-0.61**	-0.19**	-0.56*	-0.47	-0.39	-0.52*	-0.60**	-0.57**	0.67**	0.99**	1		
Cr	0.93**	-0.70**	-0.82**	-0.22	-0.60**	-0.50**	-0.55*	-0.45	-0.35	-0.50*	-0.58**	-0.55*	0.66**	0.98**	0.99**	1	
Cd	0.90**	-0.60**	-0.86**	-0.02	-0.43	-0.44	-0.40	-0.28	-0.16	-0.35	-0.41	-0.36	0.50*	0.92**	0.95**	0.97**	1

******correlation is significant at $P\leq 0.01$ level, *correlation is significant at $P \leq 0.05$ level*

4.0. Conclusions

Inland Sand mining (ISM) has occupied agricultural lands depriving agrarian communities having access to productive soil for crop production for the teaming population in the affected area whose livelihood depends entire on soil. The activities of inland sand mining has contributed both directly and indirectly to the degradation of the soil physicochemical status, resulting to strong soil acidity. According to the ratings of soil nutrients for agricultural soil, very low to low soil nutrients were recorded for total N,available P,exchangeable K, Ca and Mg in sand mined sites. The result further indicated that Copper (Cu), Lead (Pb) and Cadmium (Cd) in the sand mined sites were above the FAO/WHO permissible levels respectively, with Chromium(Cd) ≤ the FAO/WHO, limit (WHO, 1989). The potentially toxic heavy metals are in order of abundance in sand –mined soil: Cu ≥ Pb ≥ Cr ≥ Cd, with copper dominating the soil that could adversely affect man and his environment through their mobility due to strong soil acidity within upland sand mining site, resulting to soil degradation.

Based on the result of the study, active land restorations by productive use of crop husbandry and application of organic and inorganic fertilizers for soil fertility rejuvenation are encouraged.

Government should also enforce the existing mining laws that will prohibit illegal upland sand mining on the agricultural lands. The periodic environmental auditing and monitoring of the upland mining site should be embarked upon to ensure sustainable environmental quality.

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Conflict of interest

There is no conflict of interest associated with this work.

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